

# *Surviving the Impact: Core Quality Testing in a New Orbiting Sample Container for Potential Mars Sample Return*

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Jet Propulsion Laboratory,  
California Institute of Technology

International Planetary Probe Workshop 14  
June 12<sup>th</sup> – 16<sup>th</sup> 2017

## Potential MSR Overview

- Mission Concepts
- Notional landing site

## Introduction

### ADT Impact Test Stand

### Test Hardware & Instrumentation

- Sample tubes
- A representative Orbiting Sample (OS) container
- An 'Earth Entry Vehicle (EEV) like' penetrator

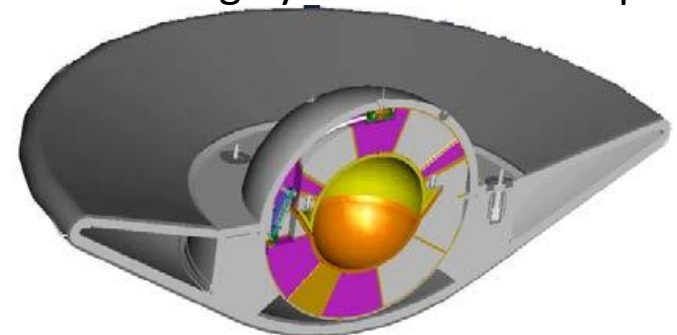
## Impact Testing

### Results

- Kinematics
- Core Quality

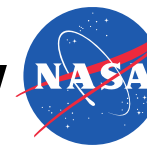
## Conclusion

NASA Langley MSR-EEV Concept



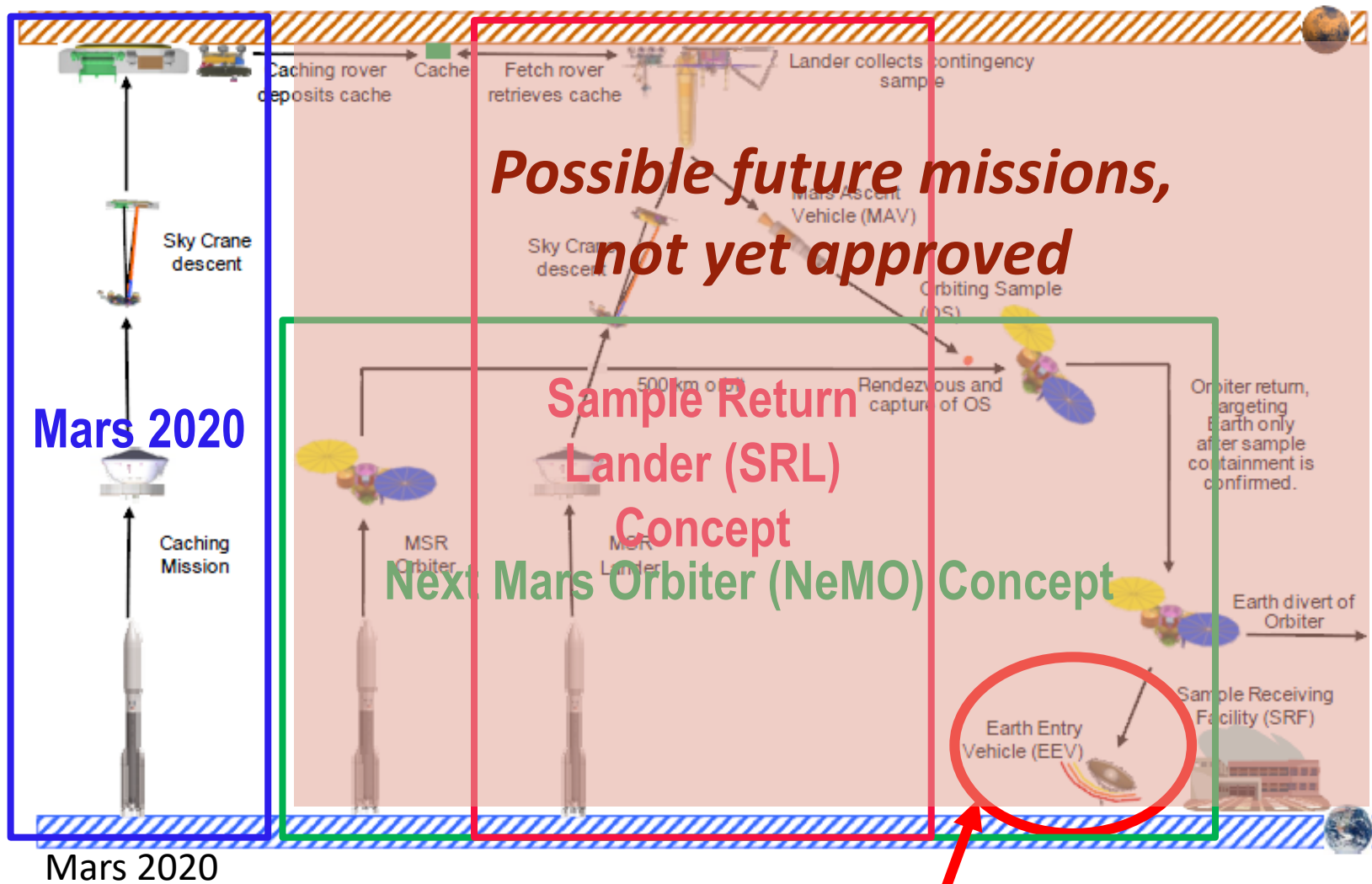
M. Munk, L. Glaab, *Mars Sample Return Earth Entry Vehicle: Continuing Efforts*. Concepts and Approaches for Mars Exploration. 2012

# Notional Mars Sample Return Overview



Jet Propulsion Laboratory  
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Mars Formulation

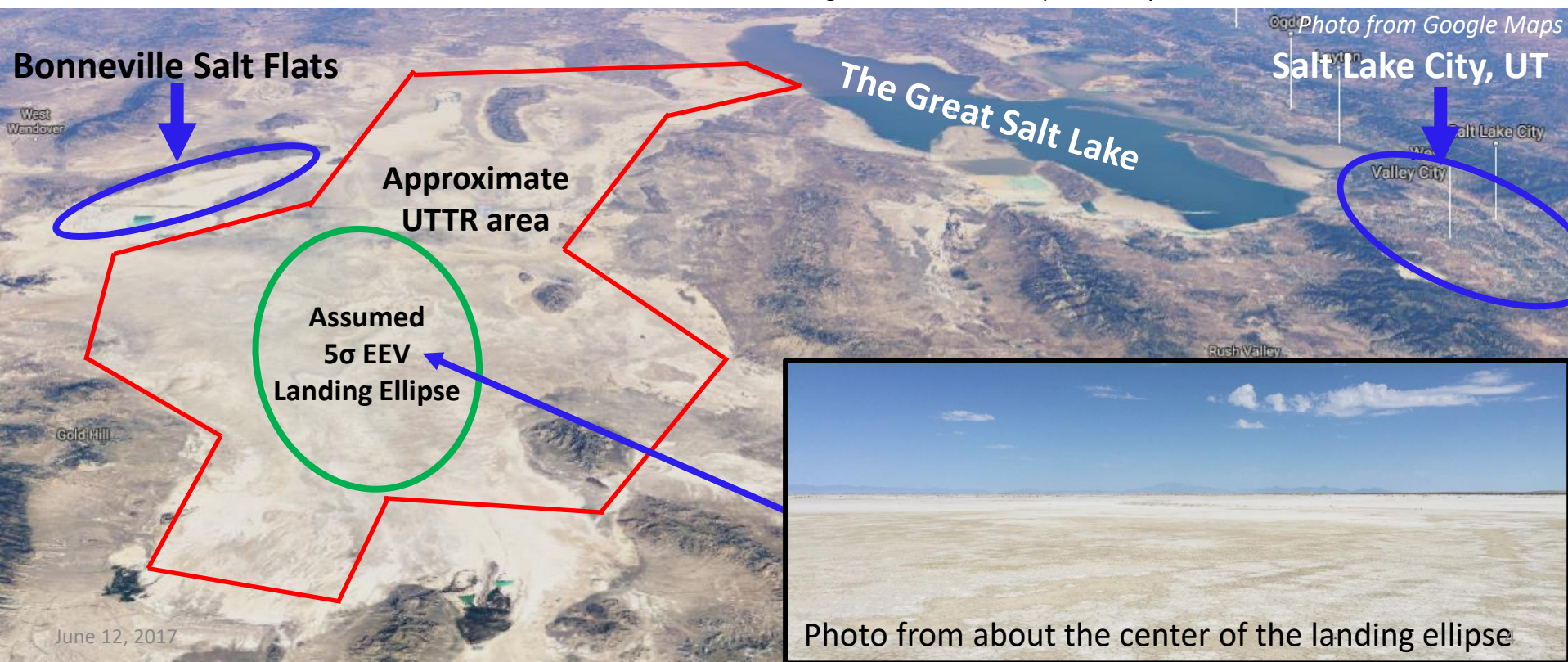


*This presentation focuses on impact testing of fragile  
'Mars like' core samples at JPL*

# Notional Earth Impact Scenario

- Notional MSR EEV would impact land at the Utah Testing and Training Range (UTTR)
- Large controlled area with consistent & soft clay soil called 'playa'
- 5 sigma landing ellipse would fit inside the range
- Anticipated EEV impacts velocity range: 30 – 50 m/sec
- Impact on the playa estimated to impart up to 1300 G on the representative EEV, OS, and tubes

Pre-Decisional Information — For Planning and Discussion Purposes Only



## Test Goal

1. Study the affect of a notional Earth impact landing on the potential future Mars samples and sample tubes
2. Determine if tube orientation during impact affects core quality.

## Approach

- Impact testing on the samples of the softest 'Mars-reference' rocks
- Conduct testing in the most realistic environment possible
  - Realistic soft soil impact conditions
  - Realistic/representative EEV, OS, and Tube hardware
  - Rock cores created using Mars 2020 developmental coring drill

# ADT Impact Tower at JPL

- 26 m tall truss frame tower with pneumatic accelerator system
- Pneumatic piston-cable system demonstrated to accelerate penetrators up to 67 m/s / 140 kJ KE
- 27x impact tests conducted with various penetrators up to 140 kg
- Soil conditions fully controllable
- High speed video of all tests for model correlation

Pre-Decisional Information — For Planning and Discussion Purposes Only

June 12, 2017





# Instrumented Test Penetrator

CAD Image

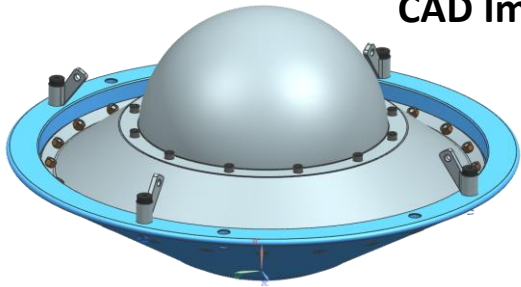
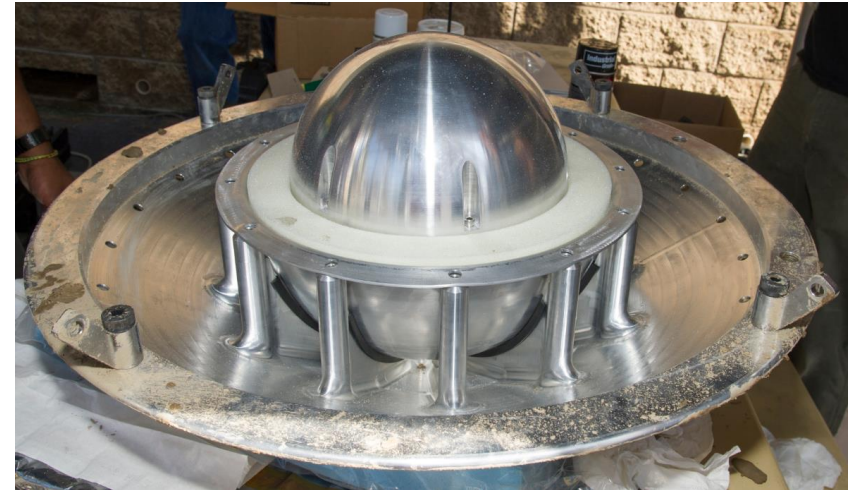


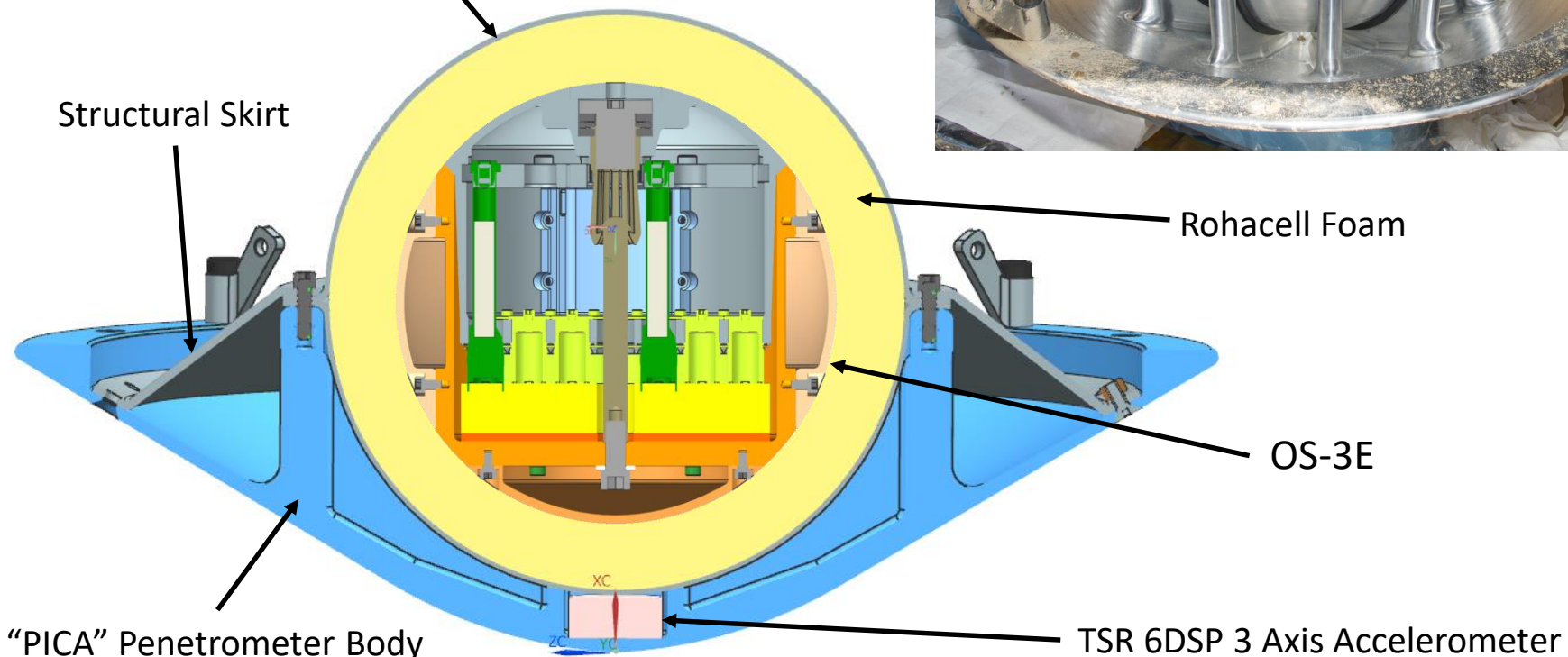
Image of penetrator after testing without the structural skirt and top housing shell



Housing Shells

Section View

Structural Skirt



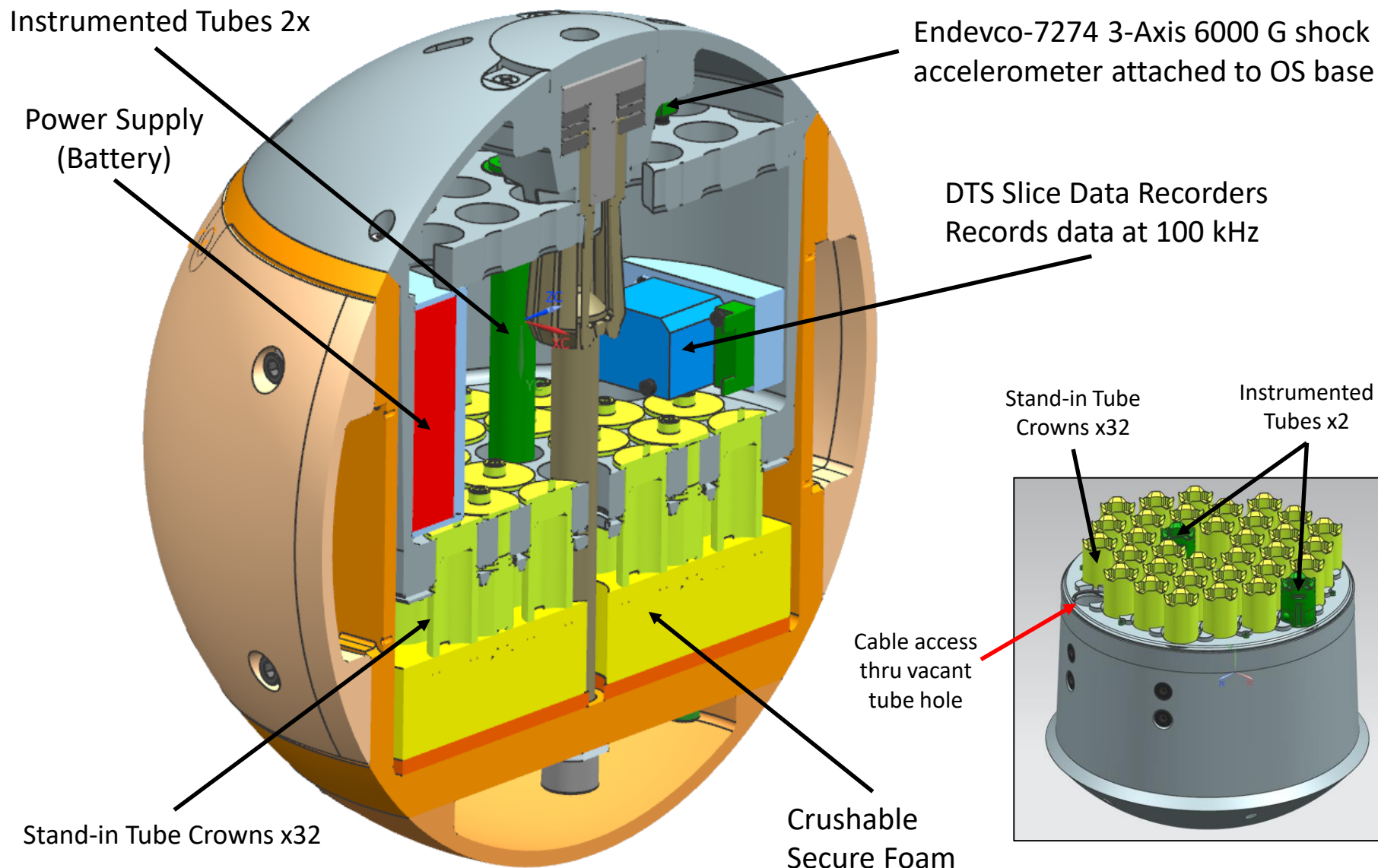
Rohacell Foam

OS-3E

"PICA" Penetrometer Body

TSR 6DSP 3 Axis Accelerometer

# Instrumented OS-3E Test Article



# OS-3E Test Article Photos

Fully Assembled



Disassembled OS Canister &  
instrumented tubes

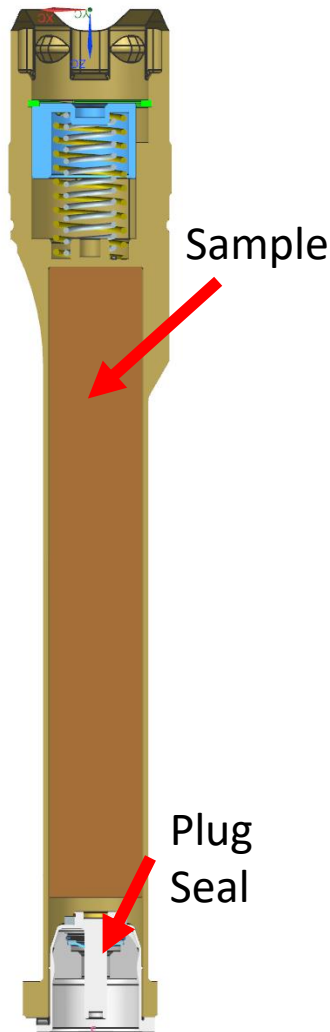
Canister and Shell - Separated



June 12, 2017

# Instrumented Sample Tube

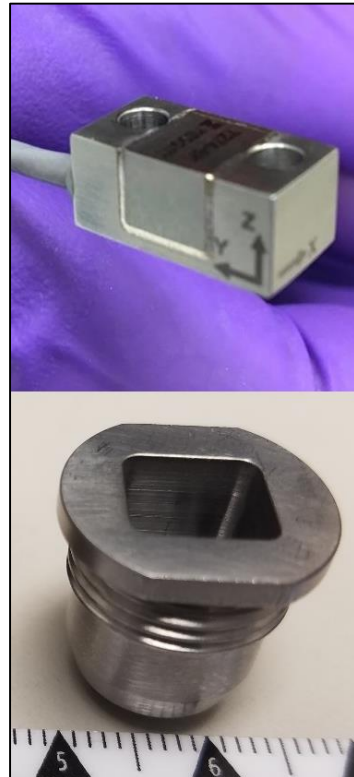
Mars 2020  
Tube CAD



Representative  
Instrumented Tube

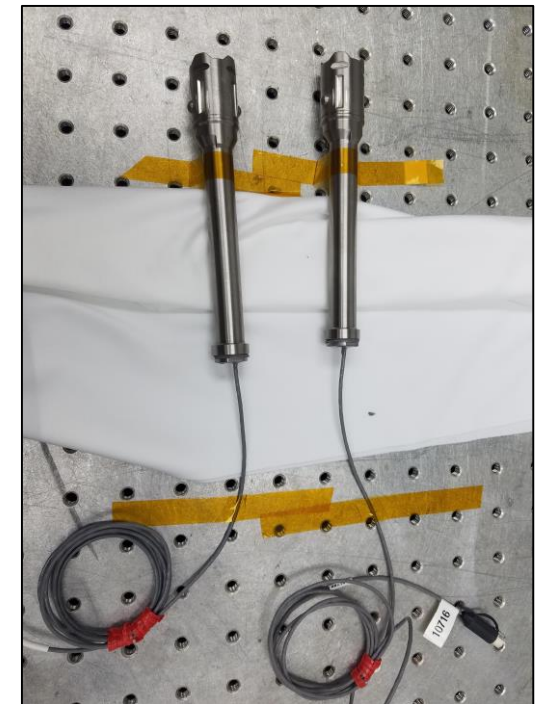


Endevco 7274-6k  
Shock Accel



Instrumented 'M2020  
like' threaded\* plug

\*Note M2020 plug seals are not threaded but have very similar external geometry to the instrumented plugs



# Impact Test Video – Full speed

- Test 1C – 47.8 m/s impact speed – Tubes ‘Vertical’



# Impact Test Video – Slow Motion

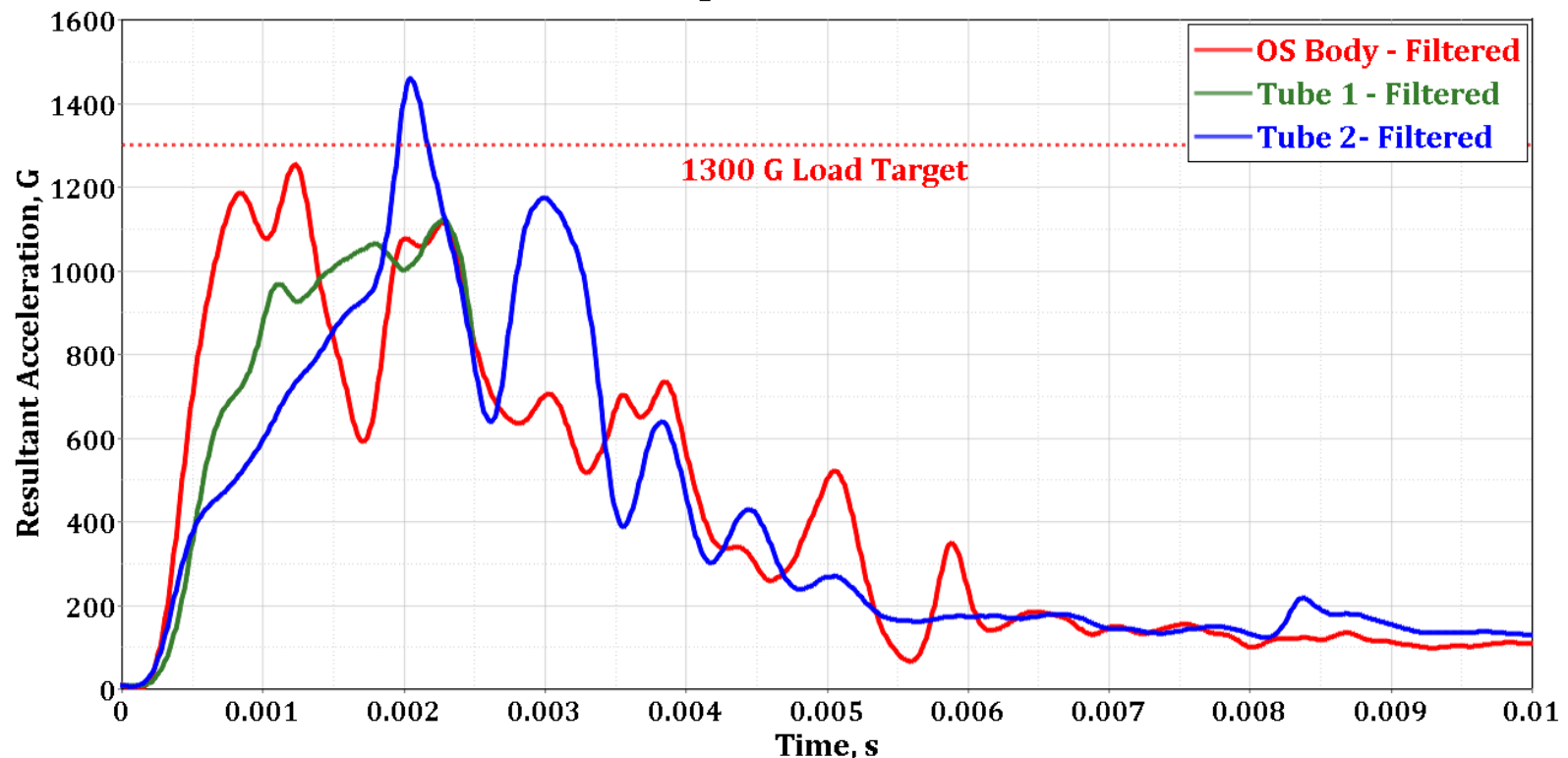
- Test 1C
- 47.8 m/s impact speed
- Tubes ‘Vertical’



# Test 1C Acceleration Results

- Target OS load was very close to the intended 1300 G requirement.
- Vehicle accel data not reported due to damage to that accel, also the Tube 1 accel plug was damaged at ~2.5 ms and so there is no good data after that.
- Because in the 90° orientation tubes are banded axially and sitting on a crushable foam base, minimal-to-no load intensification was observed at the tube tips.

Acceleration History for Vehicle, OS and Tubes  
Test 1C - 90 Deg OS - 1000 kHz J211 LP Filtered

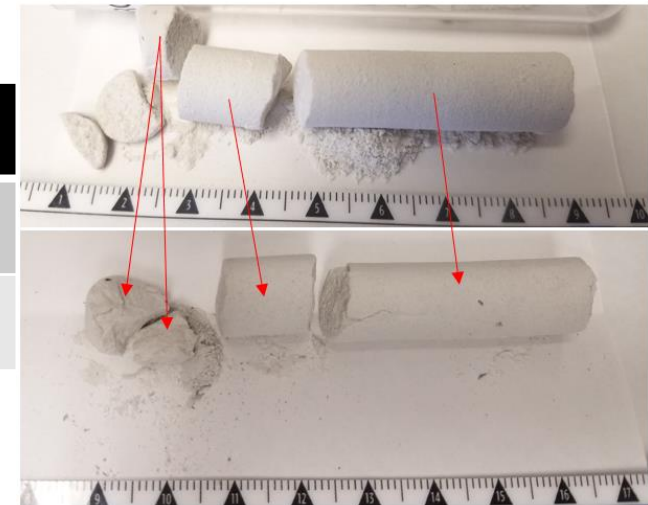


# Results: Test C1, 90° Orientation

## Exterior Tube, Sample WRC-09

### SCS Data

	Mass Not Passing 10 mm (g)	Mass Not Passing 5 mm (g)	Mass Not Passing 2 mm (g)	# Pieces Not Passing 10 mm	#Pieces Not Passing 5 mm	# Pieces Not Passing 2 mm
Pre - impact	9.276	0	0.057	4	0	9
Post-impact	8.925	0.21	0.019	3	1	6



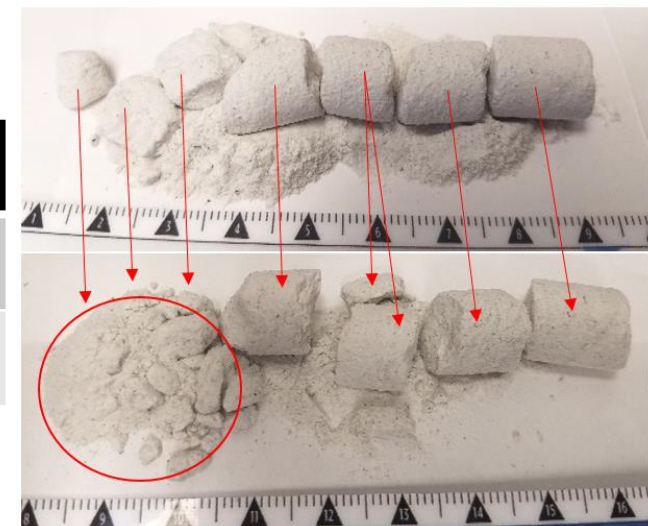
Pre-Insertion

Post-Extraction

## Interior Tube, Sample WRC-05

### SCS Data

	Mass Not Passing 10 mm (g)	Mass Not Passing 5 mm (g)	Mass Not Passing 2 mm (g)	# Pieces Not Passing 10 mm	#Pieces Not Passing 5 mm	# Pieces Not Passing 2 mm
Pre - impact	9.296	0.507	0.355	6	2	26
Post-impact	6.096	0.987	0.59	5	7	38



Pre-Insertion

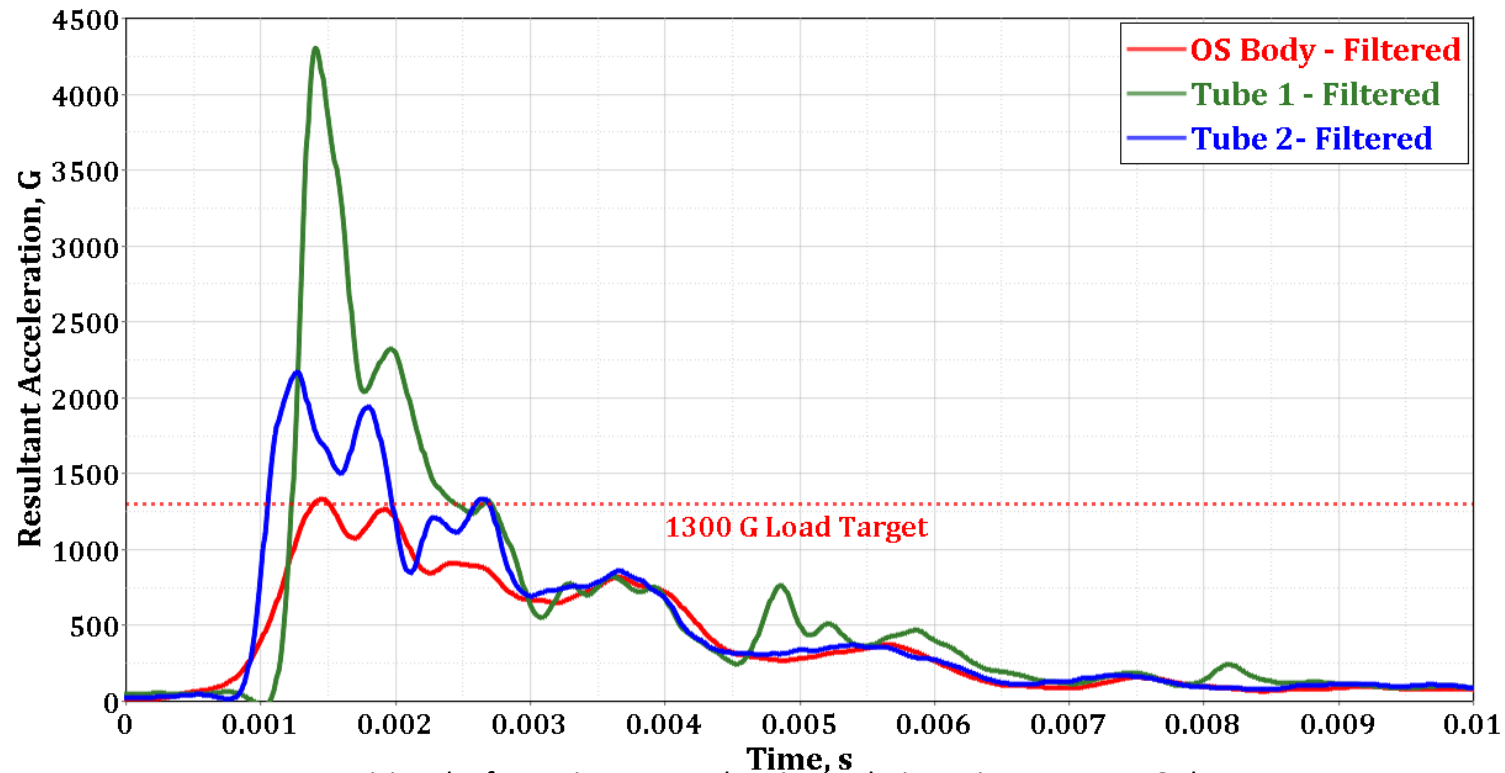
Post-Extraction

Pre-Decisional Information — For Planning and Discussion Purposes Only

# Test 1C Acceleration Results

- Again, target OS load was very close to the intended 1300 G requirement.
- For the 0° orientation, tubes are in a semi-restrained cantilevered configuration: a 0.7 mm radial gap between the tube tip and its radial restraint is needed for tube insertion into OS
- That gap at the tube tips and the cantilevered motion, generate secondary impact loads at the tips which exacerbate peak loading near the tube seals.
- Both tubes experience significant impact load intensification (upto 3X increase) due to this issue.

**Acceleration History for OS and Tubes**  
**Test 4- 0 Deg OS - 1000 kHz J211 LP Filtered**

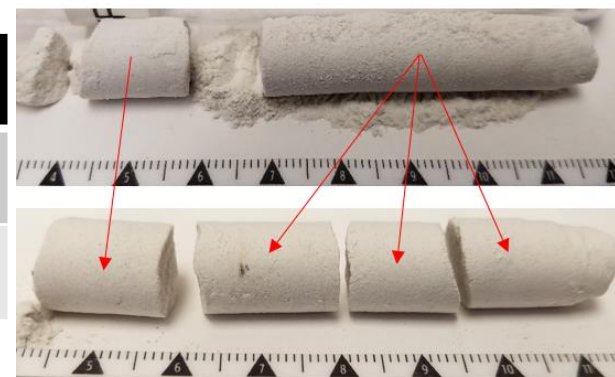


# Test C4, 0° Orientation

## Exterior Tube, Sample WRC-15

### SCS Data

	Mass Not Passing 10 mm (g)	Mass Not Passing 5 mm (g)	Mass Not Passing 2 mm (g)	# Pieces Not Passing 10 mm	# Pieces Not Passing 5 mm	# Pieces Not Passing 2 mm
Pre - impact	8.32	0	0	4	0	0
Post-impact	8.102	0	0	4	0	0



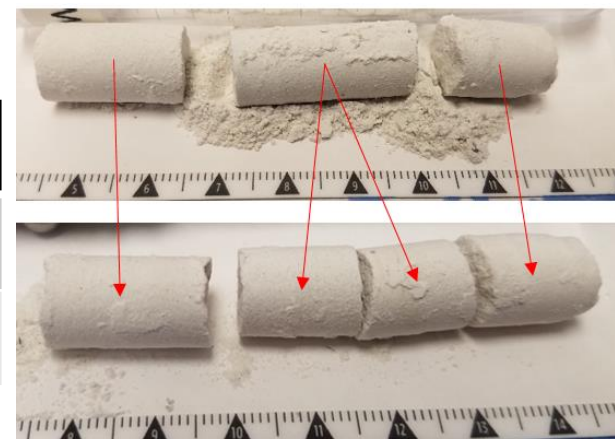
Pre-Insertion

Post-Extraction

## Interior Tube, Sample WRC-11

### SCS Data

	Mass Not Passing 10 mm (g)	Mass Not Passing 5 mm (g)	Mass Not Passing 2 mm (g)	# Pieces Not Passing 10 mm	# Pieces Not Passing 5 mm	# Pieces Not Passing 2 mm
Pre - impact	11.193	0	0.026	3	0	6
Post-impact	9.139	0	0	4	0	0



Pre-Insertion

Post-Extraction

- Mars ADT conducted 7 realistic soft soil impact tests using prototype future mission MSR hardware to determine if sample orientation and impact loads affected sample quality

***The preliminary findings from this limited test campaign are:***

1. Although all samples experienced some damage, the amount of damage was small and found to not significantly degrade their scientific value (RSS Board conclusion)
  2. Impact loads at the tube tips (near the hermetic seal) were not significantly intensified above 1300 G in the vertical 90° OS/tube orientation, but were magnified by up to 3x for the 0° orientation
  3. Despite higher tube tip loads, no scientifically significant difference in damage levels were observed for each orientation tested
  4. A correlation between pre-test core quality and impact induced damage was observed: ie. High quality samples were damaged less by impact than low quality (highly fractured) samples.
- Based off this testing and other factors, the ADT & the JPL Mars Formulation Office have adopted the vertical 90° OS/tube orientation as the baseline configuration for potential EEV Earth return.
  - Dynamic model correlation is underway and will be presented at a future time

# Thank you to the team!



*Thank you.*

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Core Quality Testing in a New Orbiting Sample  
Container for Potential Mars Sample Return*

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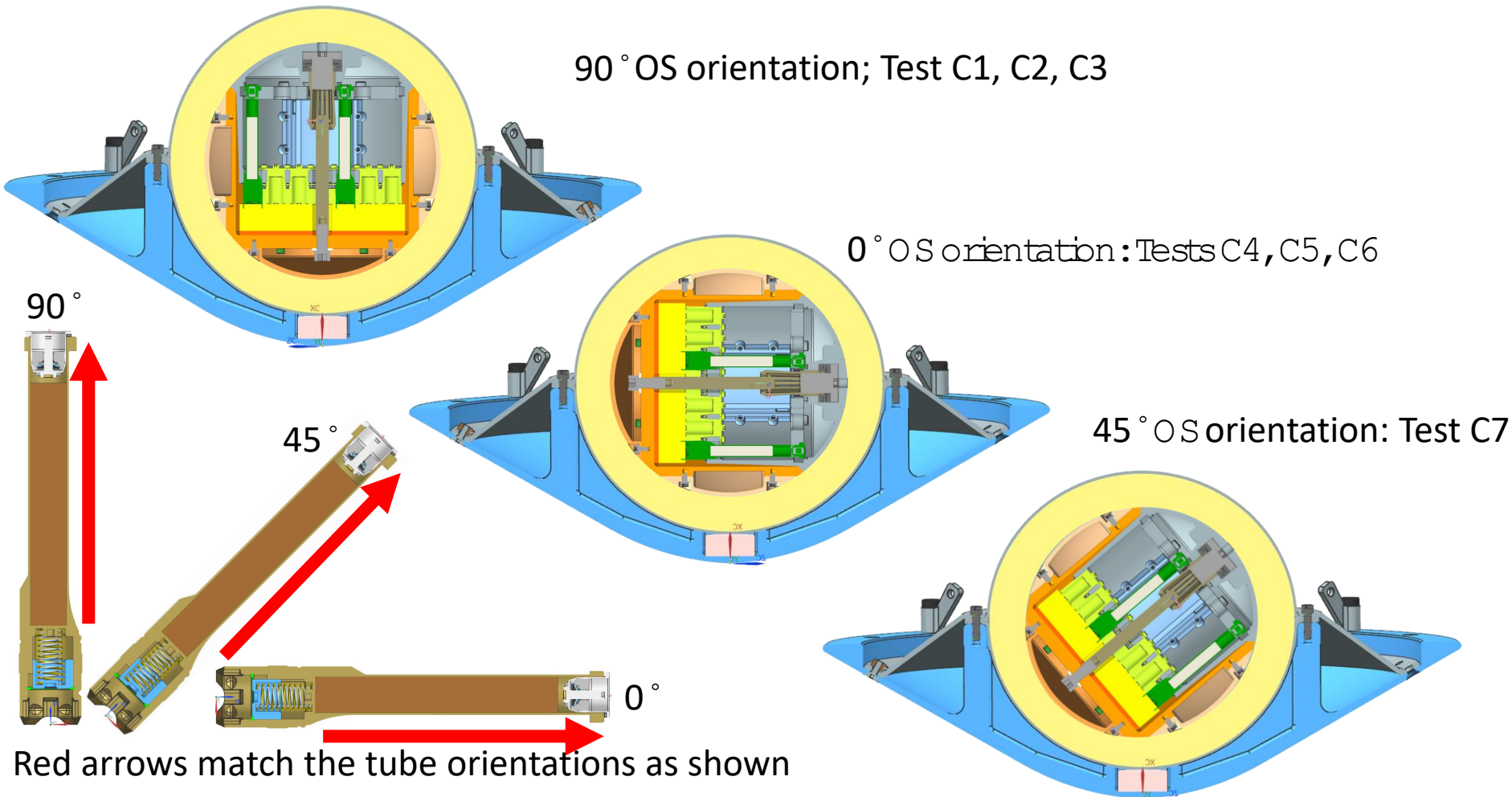
© 2016 California Institute of Technology, *Government sponsorship acknowledged*

International Planetary Probe Workshop 14  
June 12<sup>th</sup> – 16<sup>th</sup> 2017

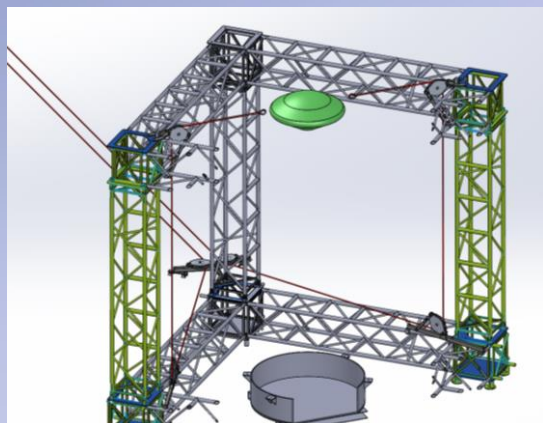
# Backup

# Test Cases: OS Orientations

*9x tests were planned, but due to time constraints only 7x were completed. All tests had, as much as possible, identical test conditions (impact velocity & soil condition)*



# Pneumatic Accelerator System



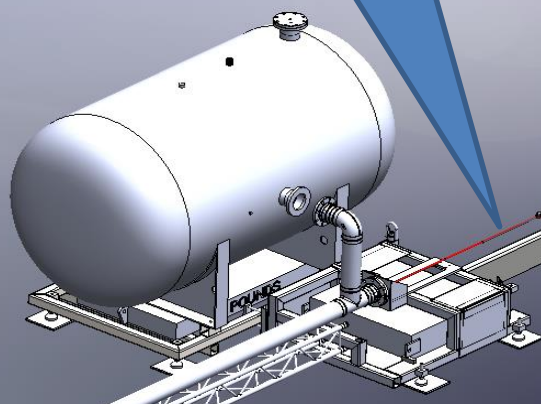
MAXIMUM TENSION – 2375  
LBS

5/8" AMSTEEL-BLUE  
Synthetic Rope  
4750 LBS MAX TENSION

1/2" AMSTEEL-BLUE  
Synthetic rope. X2

Reaction Column  
Assembly

Rope Splitter and Turnbuckles

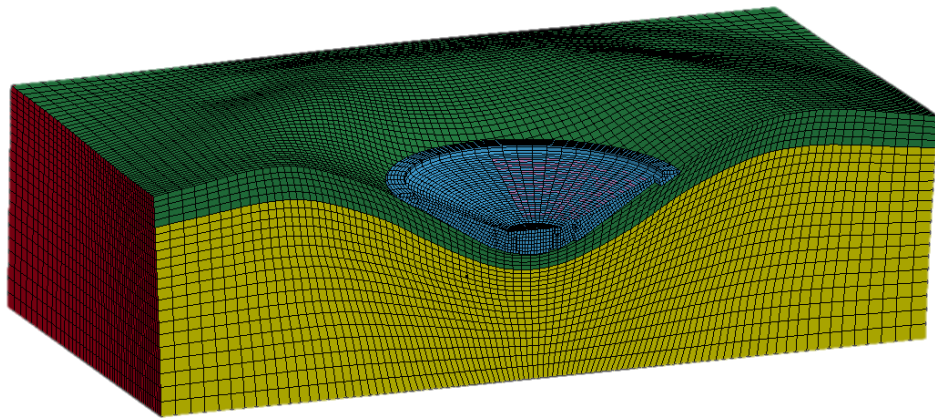


# Impact Testing and Analysis

All 14 penetrometer impact tests were modeled in LS-DYNA

Surface and sub-surface soil properties were modeled separately

A broad range of soil and penetrometer impact conditions were evaluated



# OS Concept – ‘OS-3E’

## The OS has two main components

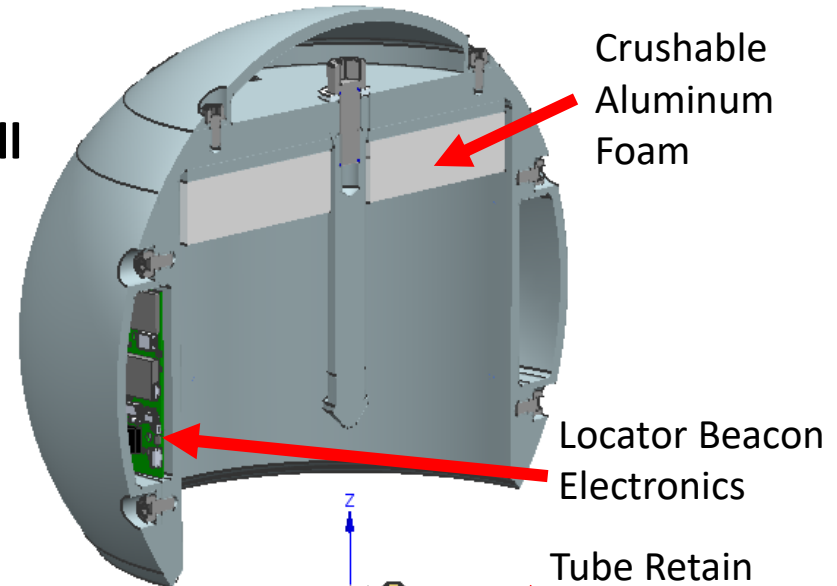
1. OS Shell: Would be secured to top of MAV before SRL launch from Earth
2. OS Canister: Would launch empty as part of fetch rover/Mobile MAV

Sub Assembly	Material(s)	Mass (kg)
OS Shell	Aluminum, Titanium, Torlon	5.7
OS Canister	Aluminum, Titanium, CRES	3.1
Beacon Electronics and Batteries	Silicon, Aluminum, Other	0.3
Atmospheric Sample Tanks	Aluminum, Other	0.3
Soil Sample Tubes	Titanium, Other	2.6
<b>Total OS Mass</b>		<b>12.0</b>

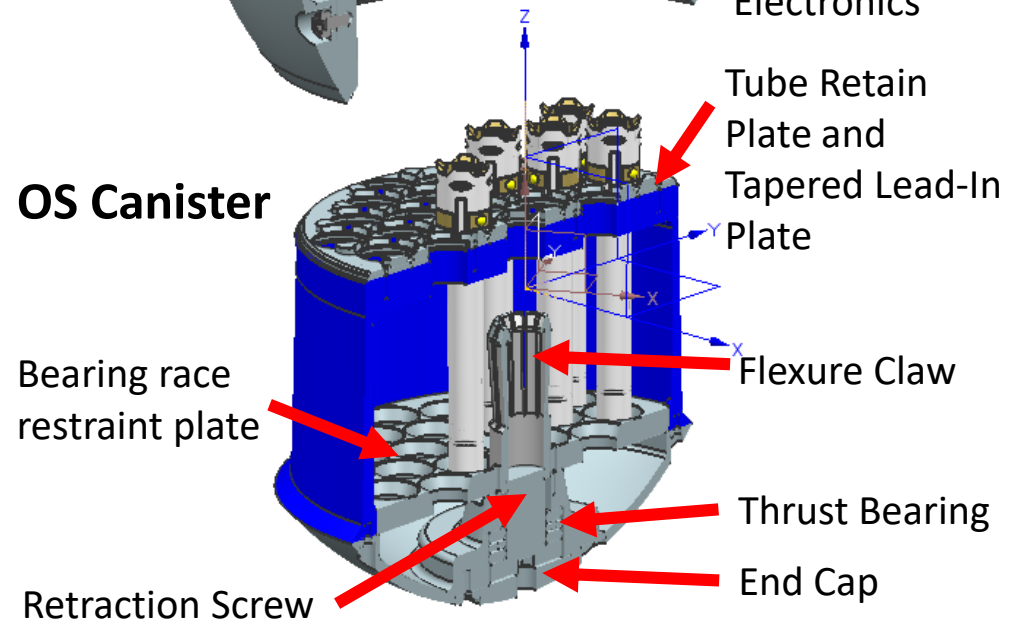
*This OS was designed as an impact test article, and thus was sized specifically to weigh 12 kg (NTE mass)*  
*Mass reductions are already underway*

## **Representative OS Design**

### **OS Shell**



### **OS Canister**

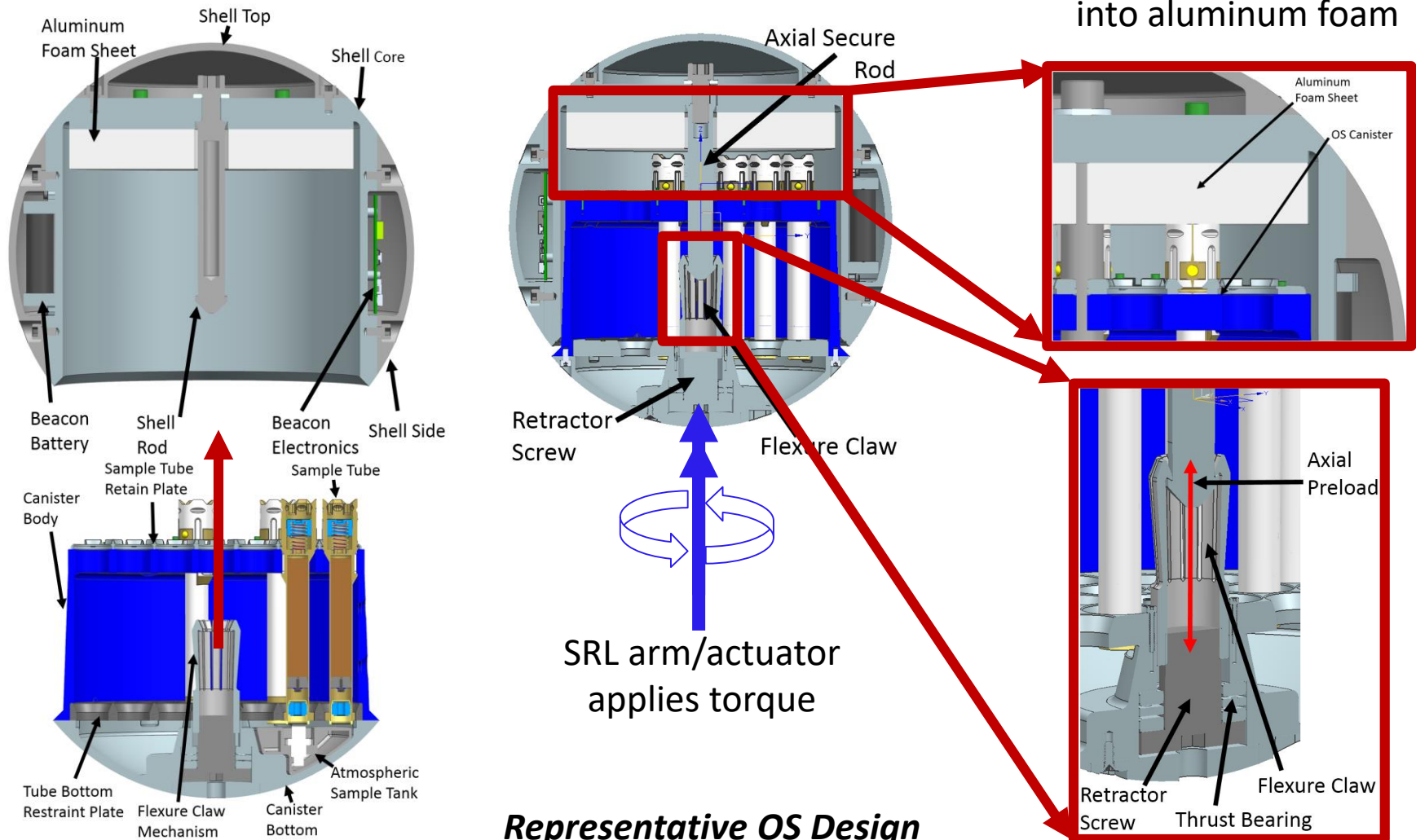


# 3 Phases to Secure OS for Launch

1. Canister would be inserted into shell

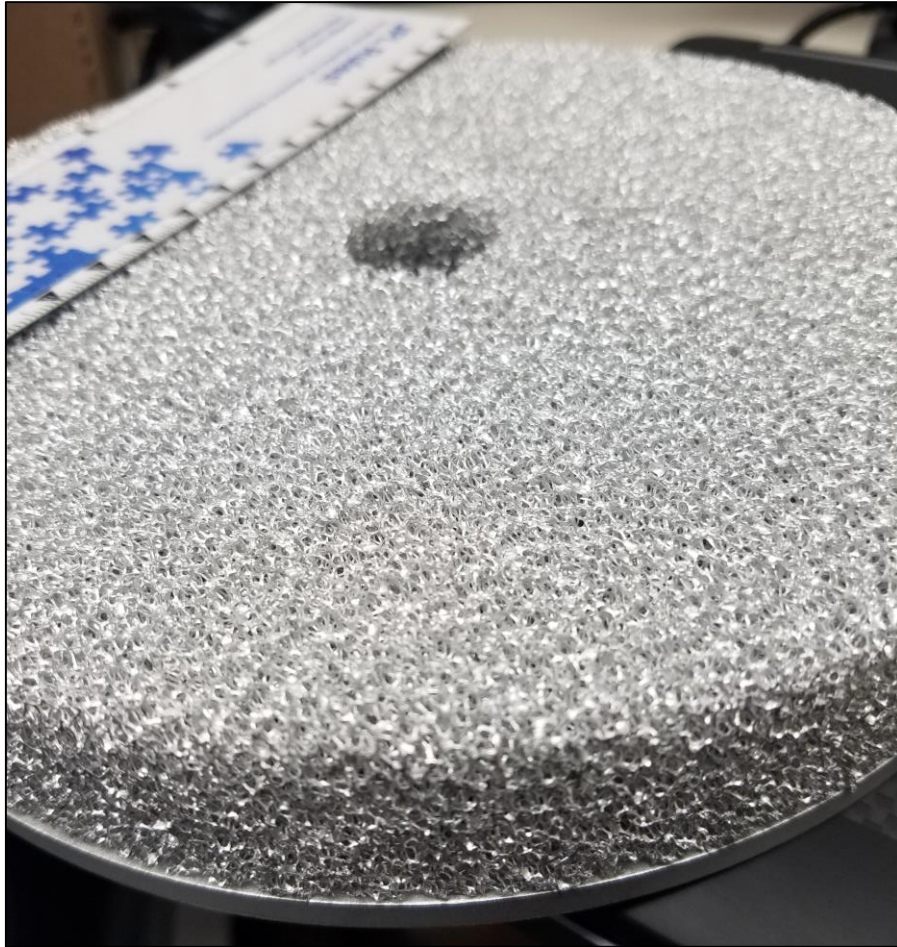
2. Flexure claw would latch onto rod

3. Torque applied: claw retracts, tubes crush into aluminum foam



# Secure Foam

Pre-impact



Post-impact

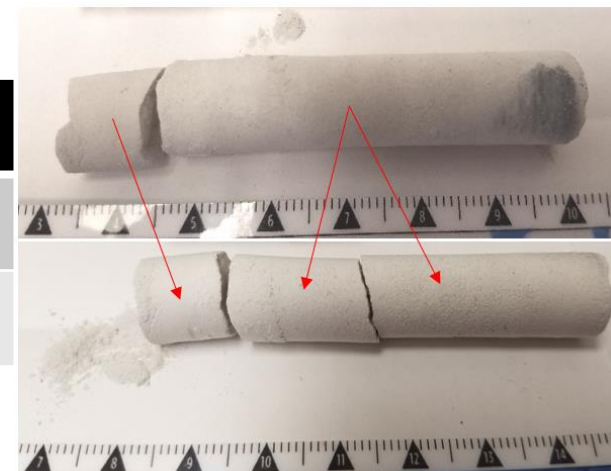


# Test C2, 90° Orientation

## Exterior Tube, Sample WRC-18

### SCS Data

	Mass Not Passing 10 mm (g)	Mass Not Passing 5 mm (g)	Mass Not Passing 2 mm (g)	# Pieces Not Passing 10 mm	# Pieces Not Passing 5 mm	# Pieces Not Passing 2 mm
Pre - impact	10.092	0	0	2	0	0
Post-impact	9.831	0.069	0.044	3	1	3



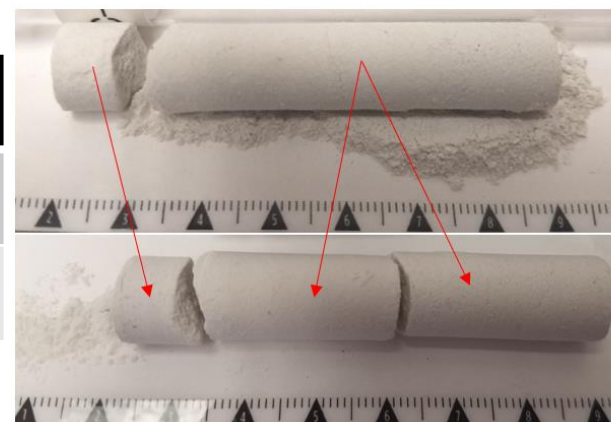
Pre-Insertion

Post-Extraction

## Interior Tube, Sample WRC-17

### SCS Data

	Mass Not Passing 10 mm (g)	Mass Not Passing 5 mm (g)	Mass Not Passing 2 mm (g)	# Pieces Not Passing 10 mm	# Pieces Not Passing 5 mm	# Pieces Not Passing 2 mm
Pre - impact	9.032	0	0	2	0	0
Post-impact	9.774	0	0	3	0	0



Pre-Insertion

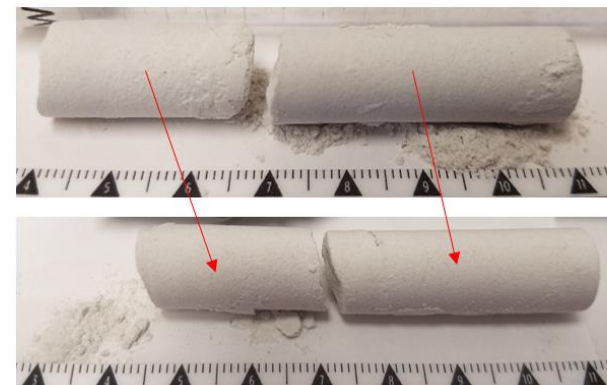
Post-Extraction

# Test C3, 90° Orientation

## Exterior Tube, Sample WRC-24

### SCS Data

	Mass Not Passing 10 mm (g)	Mass Not Passing 5 mm (g)	Mass Not Passing 2 mm (g)	# Pieces Not Passing 10 mm	# Pieces Not Passing 5 mm	# Pieces Not Passing 2 mm
Pre - impact	10.0198	0	0	2	0	0
Post-impact	9.994	0	0.005	2	0	1



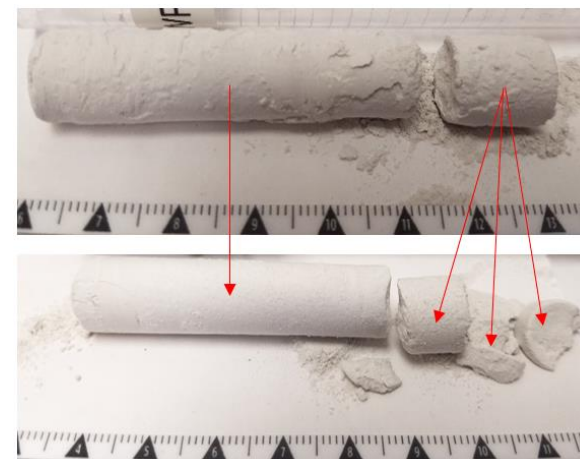
Pre-Insertion

Post-Extraction

## Interior Tube, Sample WRC-20

### SCS Data

	Mass Not Passing 10 mm (g)	Mass Not Passing 5 mm (g)	Mass Not Passing 2 mm (g)	# Pieces Not Passing 10 mm	# Pieces Not Passing 5 mm	# Pieces Not Passing 2 mm
Pre - impact	11.021	0	0	2	0	0
Post-impact	10.108	0.286	0.14	3	4	12



Pre-Insertion

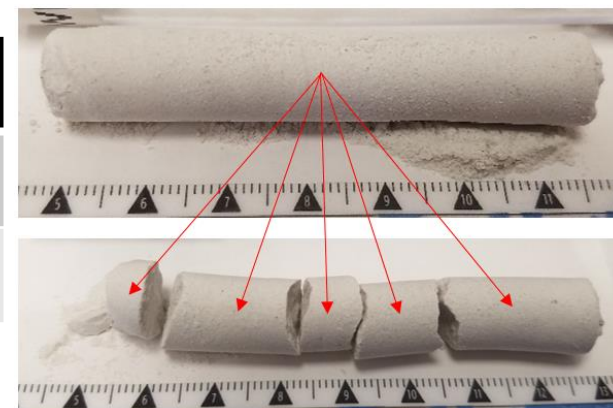
Post-Extraction

# Test C5, 0° Orientation

## Exterior Tube, Sample WRC-08

### SCS Data

	Mass Not Passing 10 mm (g)	Mass Not Passing 5 mm (g)	Mass Not Passing 2 mm (g)	# Pieces Not Passing 10 mm	# Pieces Not Passing 5 mm	# Pieces Not Passing 2 mm
Pre - impact	8.977	0	0	1	0	0
Post-impact	8.867	0	0.054	5	0	2



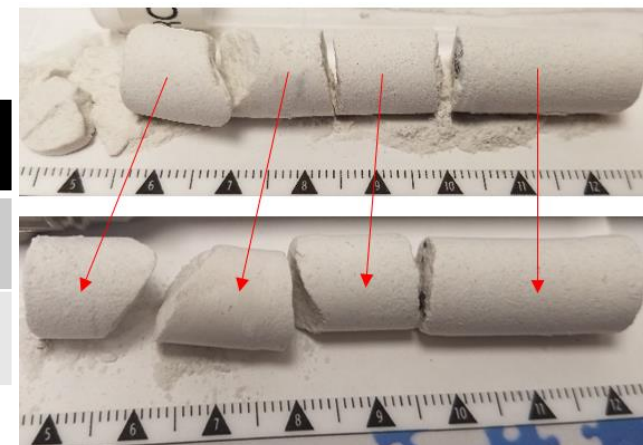
Pre-Insertion

Post-Extraction

## Interior Tube, Sample WRC-02

### SCS Data

	Mass Not Passing 10 mm (g)	Mass Not Passing 5 mm (g)	Mass Not Passing 2 mm (g)	# Pieces Not Passing 10 mm	# Pieces Not Passing 5 mm	# Pieces Not Passing 2 mm
Pre - impact	9.903	0.17	0.062	5	3	9
Post-impact	9.978	0	0	4	0	0



Pre-Insertion

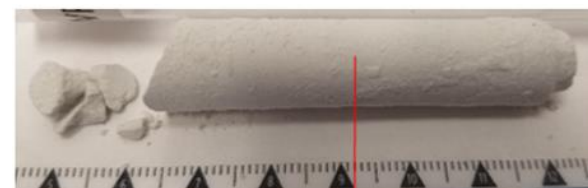
Post-Extraction

# Test C6, 0° Orientation

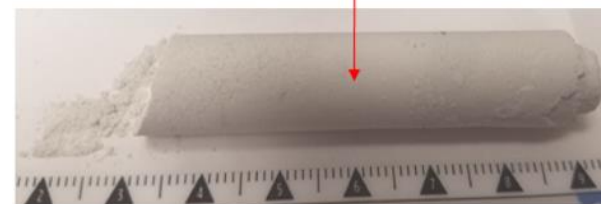
## Exterior Tube, Sample WRC-52

### SCS Data

	Mass Not Passing 10 mm (g)	Mass Not Passing 5 mm (g)	Mass Not Passing 2 mm (g)	# Pieces Not Passing 10 mm	# Pieces Not Passing 5 mm	# Pieces Not Passing 2 mm
Pre - impact	9.039	0.26	0.089	1	2	4
Post-impact	8.819	0	0	1	0	0



Pre-Insertion

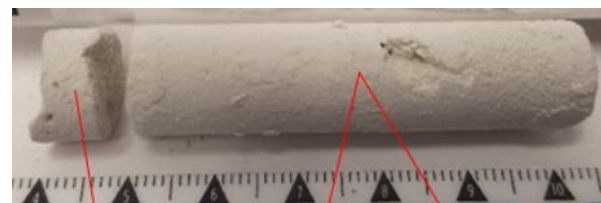


Post-Extraction

## Interior Tube, Sample PEC-219

### SCS Data

	Mass Not Passing 10 mm (g)	Mass Not Passing 5 mm (g)	Mass Not Passing 2 mm (g)	# Pieces Not Passing 10 mm	# Pieces Not Passing 5 mm	# Pieces Not Passing 2 mm
Pre - impact	8.983	0	0.006	2	0	1
Post-impact	8.831	0	0.012	3	0	2



Pre-Insertion



Post-Extraction

# Test C7, 45 ° Orientation

## Exterior Tube, Sample EDT-056

### SCS Data

	Mass Not Passing 10 mm (g)	Mass Not Passing 5 mm (g)	Mass Not Passing 2 mm (g)	# Pieces Not Passing 10 mm	# Pieces Not Passing 5 mm	# Pieces Not Passing 2 mm
Pre - impact	9.334	0.233	0.076	7	1	6
Post-impact	2.148	2.701	0.763	3	13	52



Pre-Insertion

Post-Extraction

## Interior Tube, Sample EDT-044

(SCS Data Pending)



Pre-Insertion

Post-Extraction